SPINNER
2004
A New Version

(It’s about time)

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If you Can't Get a Bigger Target...

SPINNER-2004: Objective

Improve the predictive capability capability of the SPINNER code contained within PRODAS design program

- **SPINNER computes all the Aerodynamic Coefficients of Spin-Stabilized Projectiles based on projectile geometry**

- **Most of the code was developed in 1973 (over 30 years ago). Only updates were Magnus and Spin Decay predictions**

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SPINNER-2004 I-O

- **Inputs (Geometry)**
  - **Total Length**
  - **Ogive Length, Radius**
  - **Ogive Meplat Diameter**
  - **Boattail Length, Angle**
  - **Rotating Band Dia., Length**
  - **Boom Dia., Length**
  - **Center of Gravity**
- **Outputs (Aerodynamics)**
  - **Axial Force (Drag) (function of AOA)**
  - **Normal Force**
  - **Magnus Force**
  - **Pitching Moment**
  - **Damping Moment**
  - **Magnus Moment (function of AOA)**
  - **Spin Damping**

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SPINNER Background

- **1967- Initial Development**
- **1969- First Upgrade**
- **1973- Comprehensive Re-Write w/ Spark Range & Wind Tunnel Data, Equations & Tables Constructed w/ Regression Analysis**
- **1979- Improved Spin Decay Model & Increased Data Base (1973-1979 Data)**
- **1980-1988 - Improved Magnus Model**
- **1990 Improved Short / Blunt Projectile Predictions & Increased Data Base (1979-1990)**
- **1998 Improved Magnus Model (current PRODAS V3.1 software)**

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SPINNER-2004 Methodology

- **Review and Update Data Base (over 150 projectiles)**
- **Use regression analysis to determine empirical tables and equations (technique not dependent on polynomials)**
- **Developed tables & equations assess expected errors in Aerodynamic Coefficient prediction based on statistical analysis of similar configurations to the subject projectile**

- **Result: Continuous fit across variables**

  i.e. Nose Length from 0 to 5 calibers
  Cylindrical Length from 0 to 10 calibers
  Boattail Length from 0 to 3 calibers
  any combination of variables, etc.

- **Result: Compute coefficients and their expected errors for the subject projectile**

SPINNER-2004 Data Base

- **Data Base Contents:**
  - » **Physical properties**
  - » **Key dimensions**
  - » **Aerodynamic Coefficients vs Mach and AOA**
    1. **Spark Range Experiments (primary)**
    2. **Yaw Sonde / Radar / Firing Tables (secondary)**
    3. **Wind Tunnel (supplementary)**

SPINNER-2004: Obstacles

- **Data Base of 150+ projectiles not completely adequate**
  - **Most Spark Range data before 1980 analyzed used Linear Theory.**
    - **Adequate above Mach 1.1**
    - **Inadequate below Mach 1.05**
    - **At least 50% of test results not reported**
  - **Spark Range data after 1980 analyzed using 6DOF.**
    - **Adequate at all Mach numbers tested**
  - **Wind Tunnel data inadequate (inaccurate)**
    - **Drag, Normal Force, Pitch Moment have moderate errors**
    - **Pitch Damping, Magnus, Spin Damping measurements have very large errors**

Coefficient Measurement Accuracy

Wind Tunnel and Spark Range Experimental Accuracies @ Mach 1.5

Coefficient	Wind Tunnel	Spark Range
Axial Force(Drag)	5-10%	0-2%
Normal Force	3-7%	4-8%
Pitching Moment	5-10%	0-3%
Damping Moment	Large	10-20%
Magnus Moment	Large	10-20%
Spin Damping	Large	5-10%

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Comparison of Spark Range, SPINNER '98 & 2004

Near Mach 1.5

Coefficient	Spark Range	Spinner 1998	Spinner 2004
Axial Force(Drag)	0-2%	4-9%	3-6%
Normal Force	4-8%	5-10%	3-6%
Pitching Moment	0-3%	4-8%	3-7%
Damping Moment	10-20%	15-30%	10-20%
Magnus Moment	10-20%	18-36%	15-30%
Spin Damping	5-10%	10-20%	5-10%

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SPINNER-2004 Improvement

Improvement in Std Deviation of Spinner 2004 vs 1998

Coefficient	Mach 0-0.85	Mach 0.85-1.05	Mach 1.05-2.0	Mach 2.0-6.0
Axial Force	26%	16%	21%	22%
Normal Force	22%	25%	17%	15%
Pitching Moment	27%	11%	7%	4%
Damping Moment	58%	45%	24%	27%
Magnus Moment	26%	21%	16%	16%
Spin Damping	70%	32%	28%	38%

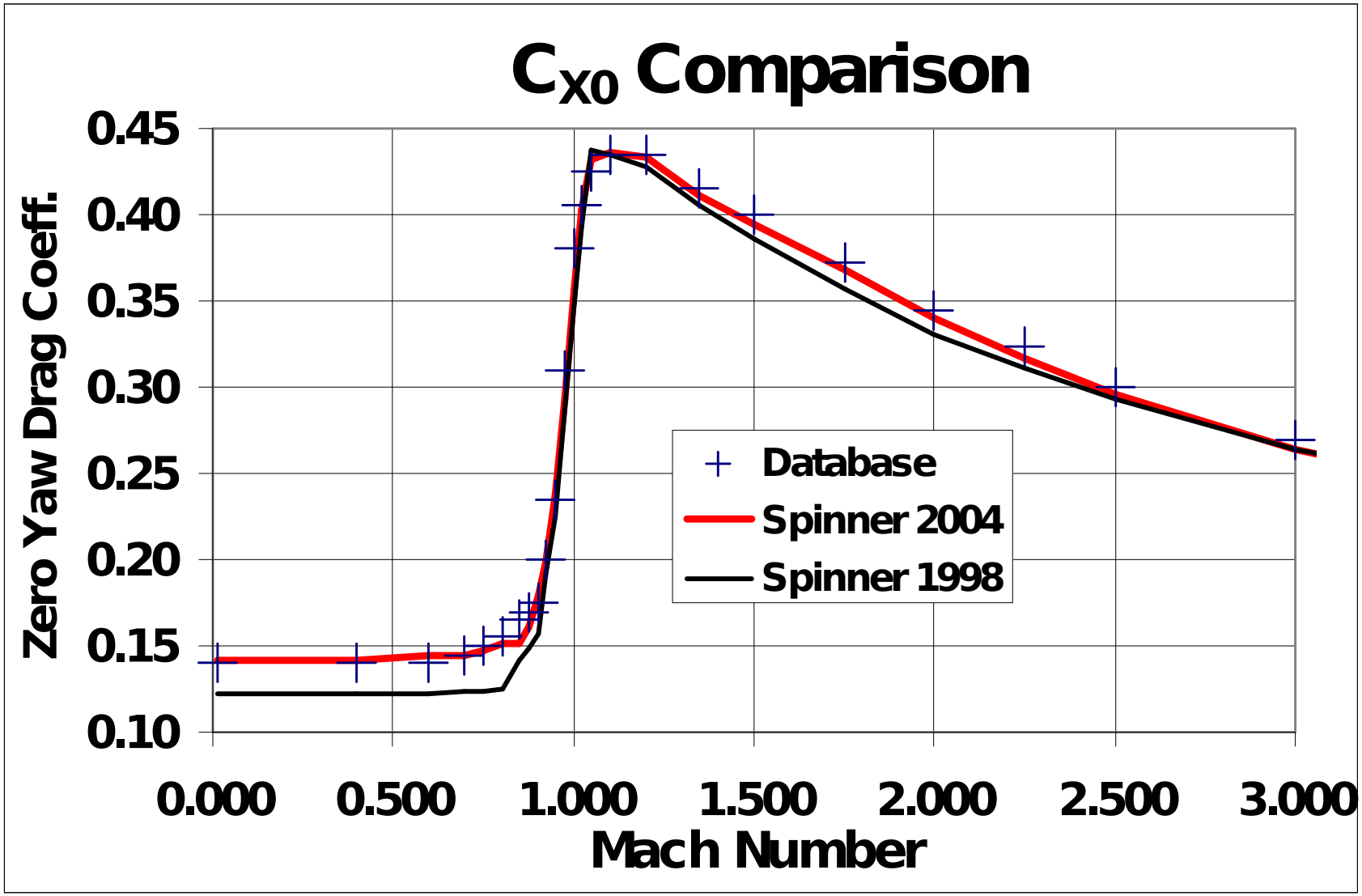
155 mm Projectile Example Results

25 Similar Projectile Shapes

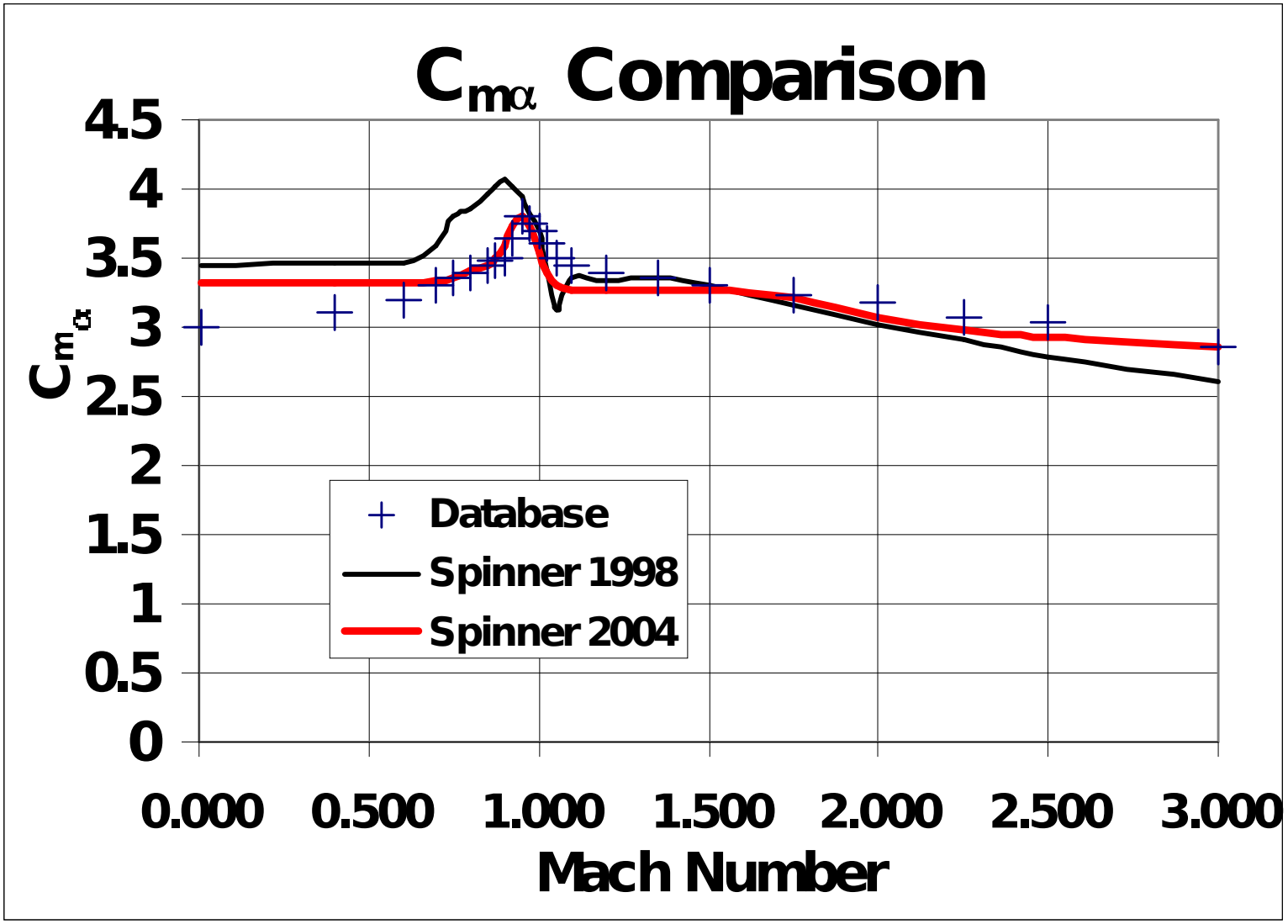
Key Projectile Dimensions (Calibers)

Projectile Length	Ogive Length	Boattail Length	Boom Length	
5.80	2.84	0.26	0.00	Subject Projectile
5.09	2.68	0.32	0.00	Mean Data Base
4.51	2.42	0.00	0.00	Minimum value
6.05	3.01	1.00	0.00	Maximum value

Results Comparison



Results Comparison



SPINNER-2004 Results

Formatted Output Example

of Samples, Std Dev. For Various Coeffs

25 Similar Projectile Shapes

Mach Number Regime	n	CX	n	CNa	n	Cma	n	CPN	n	Cmq	n	Clp
	Sample Size and Std Deviation											
Subsonic (0.010 - 0.850) =	140	0.013	139	0.13	140	0.21	140	0.11	112	2.0	97	0.0013
Transonic (0.875 - 1.050) =	163	0.020	155	0.11	163	0.29	163	0.15	131	2.0	109	0.0012
Lo Super (1.100 - 2.000) =	117	0.012	116	0.10	114	0.25	114	0.10	97	2.3	78	0.0016
Hi Super (2.250 - 4.000) =	48	0.011	45	0.09	45	0.23	45	0.08	41	2.5	26	0.0018

Magnus Moment Coefficients

Mach Number Regime	n	Cnpa 1-deg	n	Cnpa 3-deg	n	Cnpa 5-deg
	Sample Size and Std Deviation					
Subsonic (0.010 - 0.850) =	91	0.81	89	0.58	89	0.30
Transonic (0.875 - 1.050) =	114	0.87	114	0.67	115	0.33
Lo Super (1.100 - 2.000) =	97	0.32	94	0.14	94	0.13
Hi Super (2.250 - 4.000) =	41	0.19	32	0.12	32	0.12

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SPINNER-2004: Results

Coefficient	Mach 0.6	Mach 0.95	Mach 1.5	Mach 2.5
Axial Force (exp)	0.157	0.243	0.345	ND
Predicted	0.160	0.235	0.335	0.246
Abs. Difference	0.003	0.008	0.010	N/A
Predicted SD	0.013	0.020	0.012	0.011
Pitching Moment (exp)	4.31	4.50	4.65	N/D
Predicted	4.43	4.55	4.78	4.45
Abs. Difference	0.12	0.05	0.13	N/A
Predicted SD	0.21	0.29	0.25	0.23

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SPINNER-2004: Results

155 mm Projectile Example Results

Coefficient	Mach 0.6	Mach 0.95	Mach 1.5	Mach 2.5
Pitch Damping (exp)	-10.8	-17.7	-30.0	ND
Predicted	-9.0	-16.1	-32.4	-33.5
Abs. Difference	1.8	1.5	2.4	NA
Predicted SD	2.0	2.0	2.3	2.5
Magnus Moment (exp) 3 degrees AOA	-1.30	-2.20	0.45	ND
Predicted	-0.60	-0.43	0.53	0.53
Abs. Difference	0.70	1.77	0.08	NA
Predicted SD	0.58	0.67	0.14	0.12

Conclusions

- **SPINNER 2004**
  - **Identifies Number of Similar Projectile Shapes in Database for Each Coefficient**
  - **Offers Improved Prediction Accuracy for All Coefficients**
  - **Quantifies Prediction Errors by Mach number range**
  - **Increased User Confidence**

Ready for Distribution by 1 July 2004